



HAL
open science

A Preliminary Study of Fingerprint Quality Assessment of Minutiae Template

Zhigang Yao, Christophe Charrier, Christophe Rosenberger

► **To cite this version:**

Zhigang Yao, Christophe Charrier, Christophe Rosenberger. A Preliminary Study of Fingerprint Quality Assessment of Minutiae Template. 2014. hal-01076719

HAL Id: hal-01076719

<https://hal.science/hal-01076719>

Submitted on 22 Oct 2014

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

A PRELIMINARY STUDY OF FINGERPRINT QUALITY ASSESSMENT OF MINUTIAE TEMPLATE

Z. YAO¹ and C. Charrier¹, C. Rosenberger²

Université de Caen Basse Normandie¹; ENSICAEN², UMR 6072 GREYC^{1,2}, F-14032 Caen, France

ABSTRACT

Fingerprint quality is an essential factor to be considered for both enrollment and authentication phase due to the impact on the performance of biometric system. This study focuses on analyzing whether it is possible to evaluate fingerprint quality via minutiae-based template only. In order to achieve such a purpose, this study proposed several minutiae-based features which are mostly inspired by researches relating to fingerprint minutiae. Experimental results show that features computed in this study are able to contribute to fingerprint quality estimation. Experiments have been conducted on three FVC databases, and the result also has been estimated by using quality metric evaluation approach.

Index Terms— fingerprint, quality, minutiae, template, assessment

1. INTRODUCTION

Biometrics had become the first choice of security concern as usual as password-based system in last century. Fingerprint, in particular, is the most widely used biometric modality due to its invariability, usability and acceptance [1]. The application of fingerprint can be easily found nowadays, such as passport, identification card, biometric visa et etc. Correspondingly, as the deployment of this technology, quality of fingerprint sample has become an important issue and it is also a challenge, for it greatly influences the performance of a biometric system and not as easier as it is estimated by human visual perception.

Researches about fingerprint quality assessment have been carrying out since later in 1990s [2]. Researchers divided past studies into 3 types in terms of the approaches, including block-based or local qualifying approaches, global quality assessment methods, and machine learning-based solutions. The first type approaches estimate fingerprint image by dividing the image into blocks and obtain the whole image quality via a combination of each blocks quality [3, 4, 5, 6]. Second type methods qualify fingerprint image by analyzing fingerprint features in global level [2, 5, 7, 8]. By comparing these two types of approaches, it can be noticed that using only global level quality metric may ignore fingerprint local details, for a captured fingerprint image includes a large back-

ground area in most cases and it might be influenced by noises or other factors such as image specification. Local level approaches would have to bear higher computing cost. Because of this, some researches proposed to consider both local level quality criteria and global quality index which can be either linearly combined or implemented via other solutions such as supervised (classification) approaches [9, 10, 11]. In addition to NFIQ [9], among all of these approaches, none of approaches had considered minutia point quality when dealing with fingerprint quality assessment. However, minutiae quality criteria proposed in NFIQ are as well based upon image pixel information. In this study, the purpose of estimating fingerprint quality via minutiae-base template was preliminarily verified.

This study proposes several features to calculate fingerprint quality based on the triplet representation of minutia point. The calculation of features can be regarded as feature extraction phase which is followed by a utility-based quality metric approach [11]. The general framework can be described as: a minutiae template of the fingerprint image was given, in which N minutiae points represented via a triplet unit were detected by the extraction algorithm, and several potential features relating to fingerprint quality were calculated to generate a quality value of the fingerprint, as it is illustrated in figure 1.

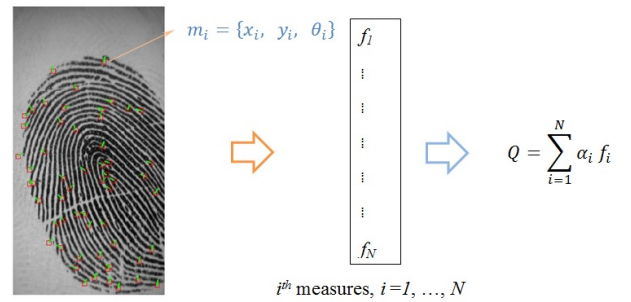


Fig. 1. Procedure of calculating minutiae-based quality metric.

In figure 1, $m_i = \{x_i, y_i, \theta_i\}$ is the minutiae representation, where (x_i, y_i) is the location of i^{th} minutiae point, and θ indicates its orientation. Once all minutiae have been ex-

tracted (referred to as minutiae template), a feature vector consisted of $f_i, i \in [1, \dots, 14]$ is computed, and Q is the quality value obtained via a linear combination of the features, where α_i is the coefficient.

In the following of the paper, section 2 presents a simple background about researches of fingerprint minutiae associated with the proposed study, especially those related to classification and matching applications. Section 3 of the paper describes the proposed minutiae-based features for calculating fingerprint quality. Section 4 details experiment and results, including the approach of generating quality metric. Conclusion and future works are given in section 5.

2. BACKGROUND

Feng *et al.* [12] proposed to reconstruct fingerprint image from the triplet representation of minutia point. In their experiment, both type-I and II attacks can be achieved on a fingerprint recognition system. This is theoretically possible to a system adopting minutiae template, for minutiae of the original template would also appear in the reconstructed image. Although there is no relation between quality and the reconstructed image, but fingerprint minutiae template does contain information which is able to reflect fingerprint quality. Arun *et al.* [13] adopt a classification approach before reconstructing fingerprint image from minutiae, in which they firstly determine the type of potential fingerprint image by considering distributions of both location and orientation information of minutiae points. In this case, it would fail to predict fingerprint type if too much noisy minutiae exist in the template. Thus, it is possible to consider that these features might be related to fingerprint quality. In addition, it is said that good quality triangle (composed by 3 minutiae points) would lead to better estimation of underlying ridges orientation. Because of this, features proposed in the paper have been considered for quality estimation.

Nevertheless, at the very beginning of the study, it was noticed that minutiae number might be related to fingerprint quality [14]. This factor, obviously, can be easily affected by spurious minutiae. However, it would show certain usability for those of relatively clear template. In addition to these features of triplet representation, some researches also proposed methods to evaluate minutia point quality [15, 16, 17], but these measures are calculated on the image. Salil *et al.* [18] proposed that minutiae type and location can be used as the auxiliary factors to improve matching accuracy. As there is no type information available in this study, this kind of information might be useful for image-based quality assessment approaches.

In this case, in addition to the features proposed in [13], this study proposed several potential features based on minutiae number and Discrete Fourier Transform (DFT) of the minutiae point to generate quality metric.

3. POTENTIAL QUALITY FEATURES

The first kind of features based on minutiae numbers and DFT of three components of minutia point are given in table 1.

Table 1. Minutiae number-based features related to fingerprint quality.

Feature	Description		NO.
Minutiae number	N_i	N_i , minutiae number of the i^{th} fingerprint.	f_1
Mean based on FT of minutiae	$mean(mag(T_i))$	$mag(T_i)$, the magnitude of the Fourier transform of minutia point's 3 components	f_2
Standard deviation of minutiae	$std(mag(T_i))$	Standard deviation of minutiae magnitude	f_3
Minutiae number in ROI ¹ 1	NR_i	NR_i , minutiae number in a rectangle region.	f_4
Minutiae number in ROI 2	NC_i	NC_i , minutiae number in a circle region.	f_5
Region-based RMS	$\frac{rms}{\sqrt{\frac{1}{n} \sum_{i=1}^n m_i^2}} =$	Root mean square (RMS) value of minutiae number based on two blocks of the template along its vertical direction.	f_6
Region-based median	$med_{\frac{1}{2}} = sort(m)$	Median value of minutiae number obtained by dividing the template into 4 blocks.	f_7
Block-based feature	A block-based quality score is calculated based on the minutiae number in each divided block of the template, the block size is score 64-by-64 here.		f_{14}

1. region of interest.

Minutiae-based features given in table ?? are computed from a the template of detected minutiae extracted by using NBIS tool [19]. This template contains a quadruple representation of minutia point which is consisted of the position of detected minutiae, (x, y), the orientation of detected minutiae, θ , and a quality score of detected minutiae. In the experiment, only the minutiae positions and orientations are used for cal-

culating these features. In the following, the details of some of the features will be presented.

For feature 2 and 3 in this experiment, these two values are derived from the magnitude of the Fourier transform of the linear combination of 3 minutia components after eliminating DC component, as in (1) and (2).

$$T(x, y, \theta) = \sum_{n=0}^{N-1} x_n \cdot \mu^{kn} + y_n \cdot \nu^{kn} + \theta \cdot \omega^{kn}. \quad (1)$$

In (1), μ , ν , and ω are frequency samples.

$$f_2 = \overline{|T(x, y, \theta)|}, \quad (2a)$$

$$f_3 = \sqrt{\frac{1}{N} \sum_{i=1}^N (T_i - f_2)}. \quad (2b)$$

DC component was eliminated when calculate these two features because there is no valuable information in this element.

For feature 4, the size of rectangle region is determined by the maximum value of both x and y coordinates of minutiae, for there is no useful information outside the foreground of the fingerprint in this case. This choice also ensures that the region of interest will not go over the effective area of minutiae. An example of rectangle region is shown in figure 2.

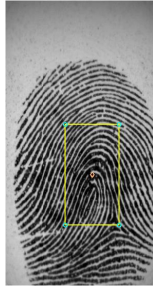


Fig. 2. Example of rectangle region.

The radius of the circle region for feature 5 is also determined by the maximum and minimum location value along the horizontal direction of fingerprint, for the minutiae located around fingerprint center are said to be those who contribute most to fingerprint matching, i.e. they are more informative. As the quadruple representation does not provide information of fingerprint core point, an estimated central point was used for as the center's location of the fingerprint. A comparison has been made between the estimated center point and a core point detected by another approach, and it is found that the result does not vary too much. The estimated center position was determined by considering the maximum and minimum minutiae location as well. An example of the circular region is shown by figure 3.

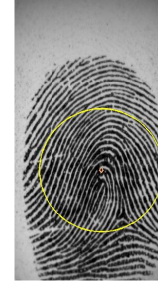


Fig. 3. Example of circular region.

For features 6 and 7, the whole fingerprint region is respectively divided into 2 and 4 blocks, and minutiae number in each block is considered to generate a feature. Another block-based feature is calculated by dividing the whole fingerprint region into several blocks in the size of 64×64 . A quality index is assigned to each block in terms of minutiae number in the block, for which a threshold is used to determine the index of each block. The block is finally classified into 3 classes: 1) reasonable block, 2) vague block, and 3) unreasonable block. Then, a feature is computed based on the number of these 3 kinds of blocks. An example of block partitioning is shown in figure 4.

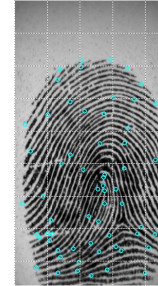


Fig. 4. Example of divided block on fingerprint image area.

In addition, features proposed in [13] are calculated in terms of minutiae distribution and orientations, and they are rotation and translation invariant. This study utilizes several of them to generate the quality metric.

4. EXPERIMENT

There are two parts in the experiment, one concerns the calculation of the quality metric, and then an evaluation is made for the expected result.

4.1. Quality Metric Generation

As alluded in section 1, the quality metric is defined as a linear combination of several features related to fingerprint quality, and it was carried out by using a utility-based approach proposed in a previous research of this study [11]. This approach

uses a genetic algorithm to generate the coefficients based on an optimization of a fitness function. The fitness function is the Pearson correlation between quality metric and genuine matching score (GMS).

In the experiment, 25% of the database were randomly selected as the training set and the remaining are used as the test set.

4.2. Protocol and Databases

In this study, three FVC databases [20] have been used for experiments: two optical sensor databases which are FVC2002DB2 and FVC2004DB1, and the third database is FVC2004DB3. Each of these 3 databases involves 100 fingertips, and 8 samples for each fingertip. In this case, the matching scores involved in the experiment have been calculated by using NBIS tool [19], Bozorth3. The intra-class scores contain $1 \times 7 \times 100 = 100$ genuine scores, and the inter-class scores are consisted of $1 \times 7 \times 99 \times 100 = 69300$ impostor scores for the whole database. Minutiae template used in the experiment was also extracted by using NBIS tool, MINDTCT.

4.3. Result

Firstly, the Pearson correlation between quality values and GMS of the database was calculated to verify the utility property of the quality metric, provided in table 2.

Table 2. Correlation analysis between GMS and quality metrics

Quality Metric \ Database		Database		
		02DB2A	04DB1A	04DB3A
Proposed		0.3857	0.1781	0.2208

As it is shown in table 2, the proposed quality index obtained a relatively good result on FVC2002DB2 among all experimental databases. In order to further verify this result, this study adopts an evaluation approach proposed in a previous result of this study [21]. For each fingertip in the database, the best sample was selected as the enrollment according to the calculated quality values of its 8 samples. Then, the EER values were computed and it was compared with the EER value calculated in the same way in terms of their NFIQ values, see figure 5.

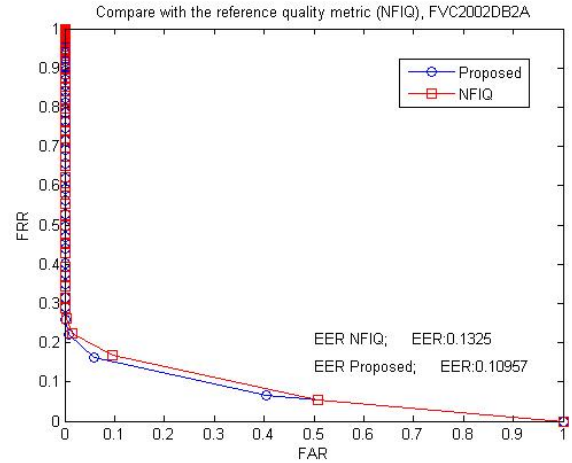


Fig. 5. Evaluation result on FVC2002DB2A

In figure 5, the EER value based on the proposed quality metric is 10.957%, and EER value based on NFIQ is 13.25%. The result shows that the proposed features are able to obtain a desired result on FVC2002DB2. This might be due to image resolution and image modes of the sensor which affect the reliability of the extracted features and lead to outliers. Actually, when comparing two optical databases in the experiment, it is able to notice that the image specifications of two databases have great difference which will greatly influence minutiae extraction algorithm. The results of two other databases are given in table 3.

Table 3. EER values of 04DB1 and 04DB3 based on choosing best quality samples as the enrollment.

Quality Metric \ Database	Database	
	04DB1A	04DB3A
Proposed	14.43%	14.44%
NFIQ	14.79%	8.4%

5. CONCLUSION

This study qualified the quality of fingerprint via minutiae template only. To do so, several features for computing quality metric were generated by considering utility property of biometric samples. With the experiment results, it was found that the features depend on several factors in addition to the minutiae extractor. It includes image specification, such as resolution or pixel density, image modes which determined the clarity of the fingerprint, image size, and contrast which directly impacts minutiae extractor. In this case, minutiae distribution model might not be appropriate to be considered for calculating quality features based on minutiae template.

Minutiae can be greatly influenced by the robustness of the extractor and this is unavoidable. The future work of the study

consider minutiae selection approach which might be able to decrease the impact caused by spurious minutiae in the template. In addition, it was also found that matching approach also impacts on the correlation result in the experiment, for the correlation was increased when a better matching algorithm was used. This is consistent with the utility property of biometric sample quality.

6. REFERENCES

- [1] Anil K Jain, Arun Ross, and Salil Prabhakar, "An introduction to biometric recognition," *Circuits and Systems for Video Technology, IEEE Transactions on*, vol. 14, no. 1, pp. 4–20, 2004.
- [2] Nalini K Ratha and Ruud Bolle, *Fingerprint image quality estimation*, IBM TJ Watson Research Center, 1999.
- [3] Rudolf Maarten Bolle, Sharathchandra Umapatirao Pankanti, and Yi-Sheng Yao, "System and method for determining the quality of fingerprint images," Oct. 5 1999, US Patent 5,963,656.
- [4] Linlin Shen, Alex Kot, and Waimun Koo, "Quality measures of fingerprint images," in *IN: PROC. AVBPA, SPRINGER LNCS-2091*, 2001, pp. 266–271.
- [5] E. Lim, Xudong Jiang, and WeiYun Yau, "Fingerprint quality and validity analysis," in *Image Processing, 2002. Proceedings. 2002 International Conference on*, 2002, vol. 1, pp. I-469–I-472 vol.1.
- [6] T.P. Chen, X. Jiang, and W.Y. Yau, "Fingerprint image quality analysis," in *Image Processing, 2004. ICIP '04. 2004 International Conference on*, 2004, vol. 2, pp. 1253–1256 Vol.2.
- [7] B. Lee, J. Moon, and H. Kim, "A novel measure of fingerprint image quality using the Fourier spectrum," in *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, A. K. Jain and N. K. Ratha, Eds., Mar. 2005, vol. 5779 of *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, pp. 105–112.
- [8] Martin Aastrup Olsen, Haiyun Xu, and Christoph Busch, "Gabor filters as candidate quality measure for nfiq 2.0," in *Biometrics (ICB), 2012 5th IAPR International Conference on*. IEEE, 2012, pp. 158–163.
- [9] Elham Tabassi, C Wilson, and C Watson, "Nist fingerprint image quality," *NIST Res. Rep. NISTIR7151*, 2004.
- [10] M. El-Abed, R. Giot, B. Hemery, C. Charrier, and C. Rosenberger, "A svm-based model for the evaluation of biometric sample quality," in *Computational Intelligence in Biometrics and Identity Management (CIBIM), 2011 IEEE Workshop on*, April 2011, pp. 115–122.
- [11] Mohammad El Abed, Alexandre Ninassi, Christophe Charrier, and Christophe Rosenberger, "Fingerprint quality assessment using a no-reference image quality metric," in *European Signal Processing Conference (EUSIPCO)*, 2013, p. 6.
- [12] Jianjiang Feng and Anil K Jain, "Fingerprint reconstruction: from minutiae to phase," *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. 33, no. 2, pp. 209–223, 2011.
- [13] Arun A Ross, Jidnya Shah, and Anil K Jain, "Toward reconstructing fingerprints from minutiae points," in *Defense and Security*. International Society for Optics and Photonics, 2005, pp. 68–80.
- [14] L. Hong, Yifei Wan, and A. Jain, "Fingerprint image enhancement: algorithm and performance evaluation," *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. 20, no. 8, pp. 777–789, 1998.
- [15] Jiansheng Chen, Fai Chan, and Yiu-Sang Moon, "Fingerprint matching with minutiae quality score," in *Advances in Biometrics*, Seong-Whan Lee and StanZ. Li, Eds., vol. 4642 of *Lecture Notes in Computer Science*, pp. 663–672. Springer Berlin Heidelberg, 2007.
- [16] Partha Bhowmick, "Determination of minutiae scores for fingerprint image applications," in *Proc. 3rd Indian Conference on Computer Vision, Graphics and Image Processing*, 2002, pp. 463–468.
- [17] Xiaolong Zheng, Yangsheng Wang, Xuying Zhao, and Zheng Wei, "A scheme for minutiae scoring and its application to fingerprint matching," in *Intelligent Control and Automation, 2008. WCICA 2008. 7th World Congress on*, June 2008, pp. 5917–5921.
- [18] Salil Prabhakar, Anil K Jain, and Sharath Pankanti, "Learning fingerprint minutiae location and type," *Pattern recognition*, vol. 36, no. 8, pp. 1847–1857, 2003.
- [19] Craig I Watson, Michael D Garris, Elham Tabassi, Charles L Wilson, R Michael McCabe, Stanley Janet, and Kenneth Ko, "User's guide to nist biometric image software (nbis)," 2007.
- [20] Dario Maio, Davide Maltoni, Raffaele Cappelli, Jim L Wayman, and Anil K Jain, "Fvc2004: Third fingerprint verification competition," in *Biometric Authentication*, pp. 1–7. Springer, 2004.
- [21] Z. YAO, C. Charrier, and C. Rosenberger, "Utility validation of a new fingerprint quality metric," in *International Biometric Performance Conference 2014*. National Insititure of Standard and Technology (NIST), April 2014.